THE GREY TO GREEN INFRASTRUCTURE TRANSITION - AN HISTORICAL SHIFT IN THE MODERN INFRASTRUCTURE PARADIGM

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WHAT WE'LL DISCUSS THIS MORNING

- From Whence We've Come
- "Modern" Stormwater Management
- "Future" of Stormwater Management
- The What's
- The How Well's
- Concluding Remarks

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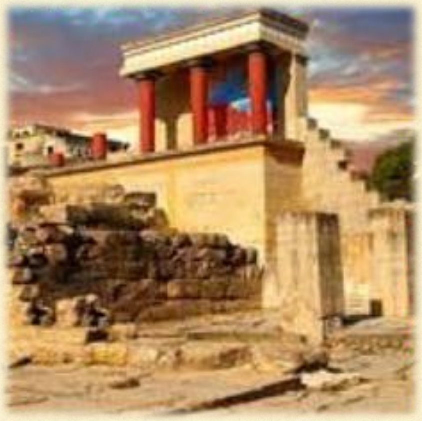
FROM WHENCE WE'VE COME

MILLENIA HISTORY OF WATER COLLECTION AND CONVEYANCE

- Mohenjo Daro in Indus Valley
  - 2600 to 1900 BC

MILLENIA HISTORY OF WATER COLLECTION AND CONVEYANCE



- Knossos, Crete
  - Great Palace - 1700 to 1400 BC

MILLENIA HISTORY OF WATER COLLECTION AND CONVEYANCE

Pont du Gard, France, 19 BC

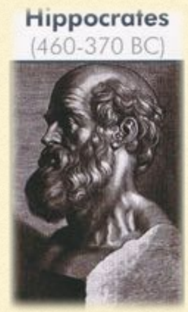
- Rome founded 753 BC, Empire Ends 476 AD
  - Engineers of the Ancient World

Cloaca Maxima, 600 BC

MILLENIA HISTORY OF WATER COLLECTION AND CONVEYANCE

- Archaic to Hellenistic Greece
  - Contemporary of Romans - 800 to 146 BC

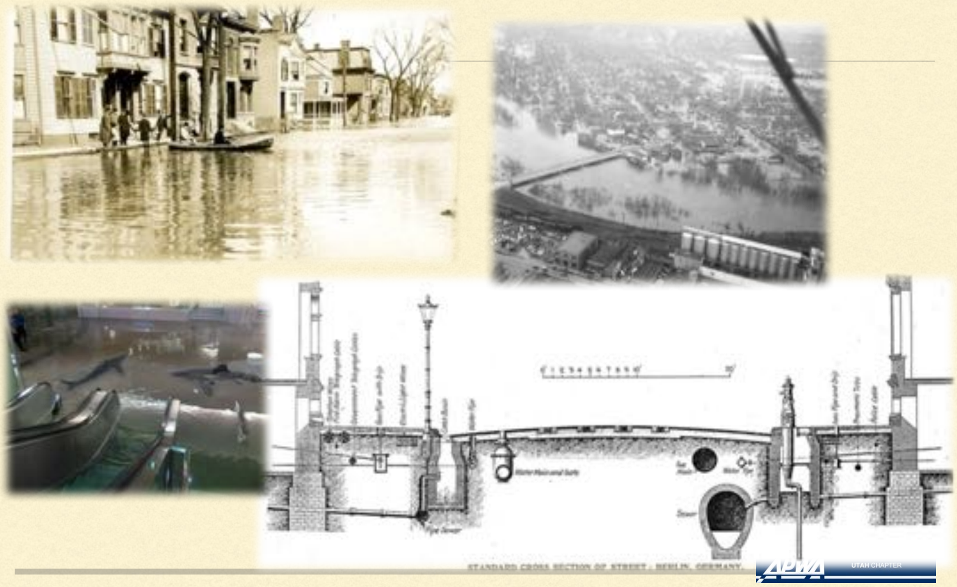
Drains in Pella, 350 BC



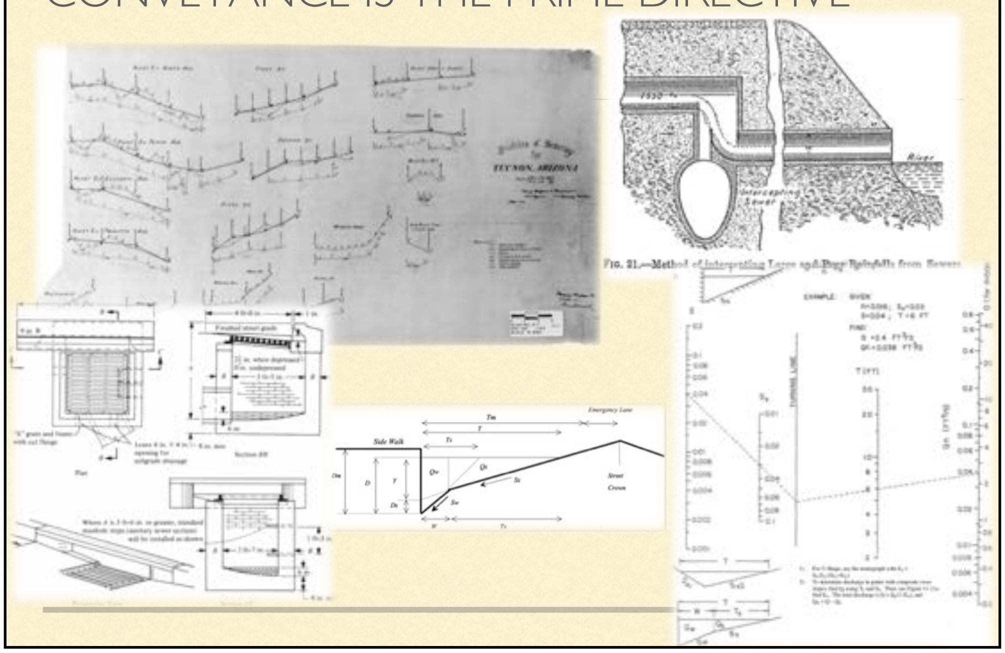
"On Airs, Waters, and Places," 400 BC

"MODERN" STORMWATER MANAGEMENT

PROTECTION OF PUBLIC HEALTH & SAFETY & PREVENTION OF PROPERTY DAMAGE



CONVEYANCE IS THE PRIME DIRECTIVE



WHEN CONVEYANCE IS THE PRIME DIRECTIVE

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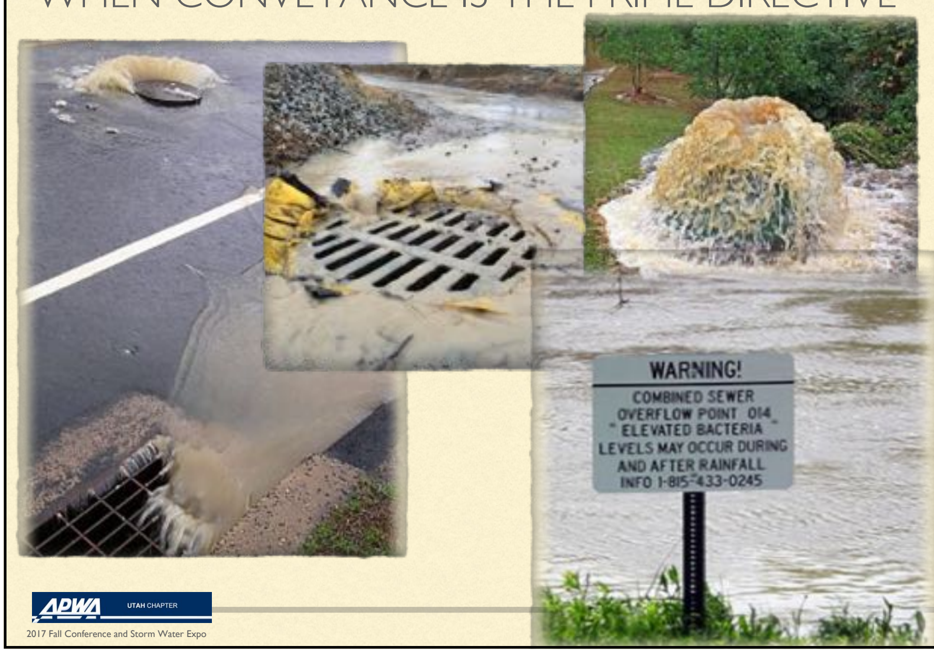

"FUTURE" STORMWATER MANAGEMENT – GREEN INFRASTRUCTURE & LID

GI/LID DESIGN PRINCIPLES

Engineered Systems to Ensure that Human Activities DO NOT Exceed Assimilative Capacity of Receiving Environment (Water, Pollutants, Heat, etc.)

GI/LID DESIGN PRINCIPLES

- Move from Historical Centralized Stormwater Collection and Rapid Conveyance
- TO **Distributed** Management
- Design to **Minimize** Impact TO
  - Receiving Ecosystem
  - Water Supplies
  - Livability of Own & Downstream Communities

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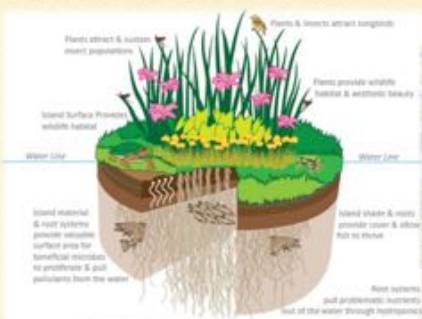
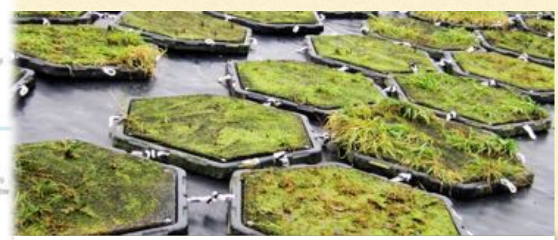
THE WHAT'S

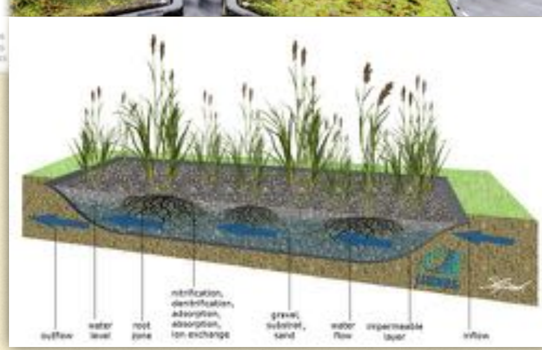
GREEN INFRASTRUCTURE & LOW IMPACT DEVELOPMENT OPTIONS

CONSTRUCTED WETLANDS





Constructing Wetlands	
Water management benefits	**Co-benefits**
• Water supply regulation (incl. drought mitigation) • Flood mitigation • Water purification and biological control • Water temperature control	• Biodiversity benefits (incl. pollination) • Recreational, aesthetic value • Reduced water treatment costs • Livelihood income possibilities • Climate change adaptation and mitigation (carbon storage and sequestration)



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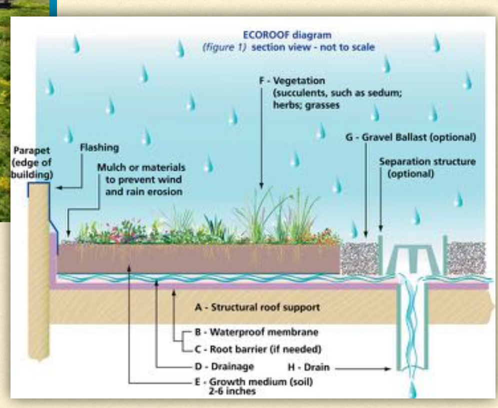
MORE CONSTRUCTED WETLAND DESIGNS FOR STORMWATER

GREEN ROOFS

© Chesapeake Bay Program

Green roofs	
Water management benefits	Co-benefits
• Flood mitigation (urban stormwater control)	• Biodiversity benefits • Aesthetic value • Improved air quality • Reduced noise pollution • Carbon sequestration • Energy savings (reduced cooling and heating needs) • Reduced urban heat island effect



GREEN ROOFS, SLC

GREEN ROOFS

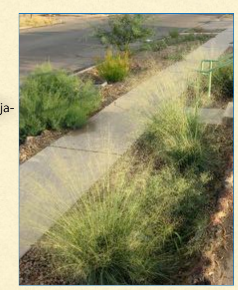
RAIN GARDENS, BIOSWALES

Green spaces	
Water management benefits	Co-benefits
• Flood mitigation (stormwater runoff control) • Water purification • Water supply regulation (improved groundwater recharge) • Temperature control (shading of water ways)	• Biodiversity benefits • Aesthetic value • Improved air quality • Energy savings for water treatment • Carbon sequestration • Reduced urban heat island effect • Reduced noise pollution

CURB CUTS & SWALES

This long, shallow ROW swale has multiple curb cuts along its length.

This series of basins collects stormwater from the adjacent sidewalk and businesses (without curb cut).



IN STREET OPTIONS LOW MOISTURE SETTINGS

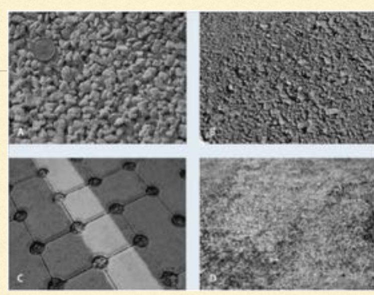
Too
Much
Street
!

Traffic circle

Chicane

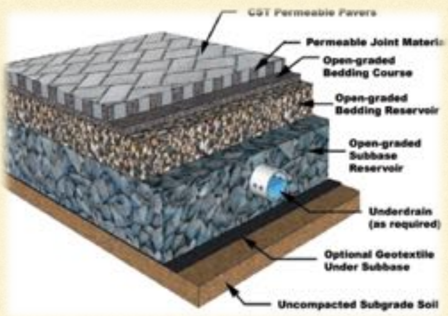
Median

POROUS PAVEMENTS



Permeable pavements	
Water management benefits	**Co-benefits**
• Flood mitigation (stormwater runoff control) • Water purification • Water supply regulation (improved groundwater recharge)	• Improved air quality • Reduced urban heat island effect • Reduced noise pollution

POROUS PAVEMENTS



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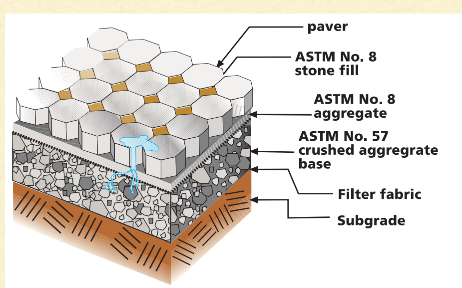
POROUS PAVEMENTS

Figure 10: Permeable Pavers and Permeable Concrete Chicago Alleys
(Source: Abby Hall, US EPA)



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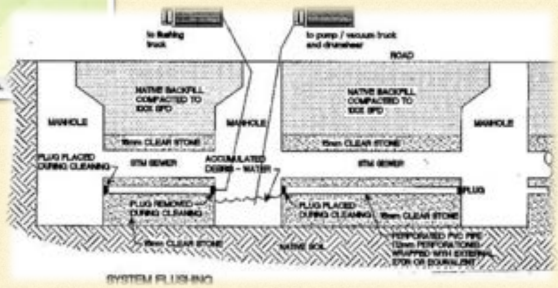
INFILTRATION CONVEYANCE SYSTEM – ONTARIO, CANADA

Figure 1. Layout of Etobicoke exfiltration system.



RAINWATER HARVESTING

Water harvesting	
Water management benefits	**Co-benefits**
• Water supply regulation (water storage and improved groundwater recharge) • Flood mitigation (reduced stormwater runoff) • Water purification (increased infiltration)	• Reduced costs of water conveyance and treatment, energy savings • Climate change adaptation, increased resilience • Maintained crop productivity, soil conservation • Cultural value, preservation of traditional knowledge

Commercially sized cistern at the Chicago Center for Green Technology. *Photo: Abby Hall, EPA.*

THE HOW WELL'S - ISSUES REMAIN

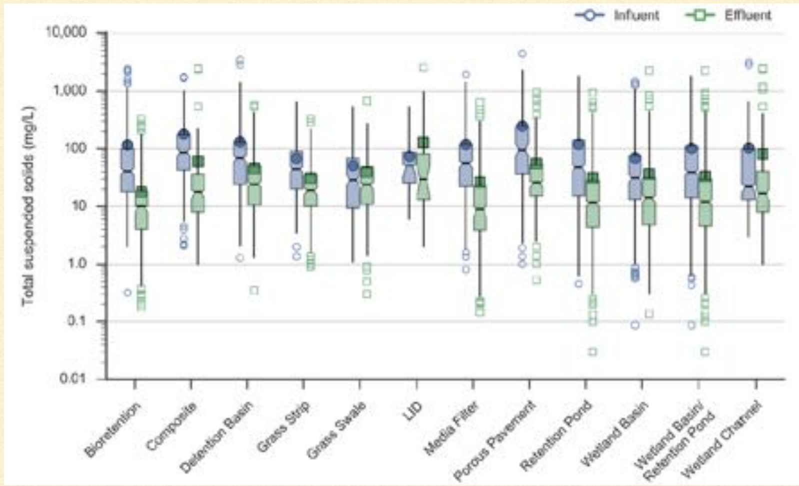
- What is Feasible in Arid Regions?
- How Well Do these Systems Perform?
- What is Appropriate Approach for New & Retrofitted Systems?
- How Do We Make them Sustainable?

LACK OF INFORMATION ON GI PERFORMANCE IN INTERMOUNTAIN WEST

- International Stormwater BMP Database Primary Source of BMP/LID/GI Performance

Category	2016 Count
Bioretention	59
Composite	29
Detention Basins (Dry)	53
Green Roofs	17
Grass Strip	45
Grass Swales	44
Infilt. Basin	2
LID Sites	10
Manufact. Devices	113
Media Filters	41
Maintenance	29
Other	6
Permeable Pavent	48
Perc. Trench	13
Retention Pond (Wet)	78
Rain Harvesting	1
Wetland Basin	39
Wetland Channel	23
Total BMPs	650
Control Sites	30

PERFORMANCE ALL OVER THE PLACE!



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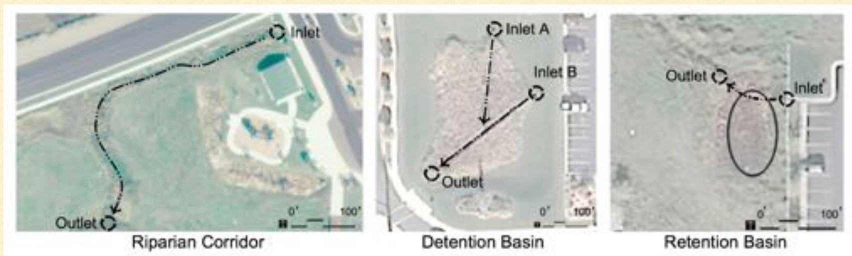
SERIES OF STUDIES OVER LAST 10 YEARS TO ASSESS PERFORMANCE OF BMPS & GI SYSTEMS IN NORTHERN UTAH

- Field Evaluation of Three BMPs in Logan
- Greenhouse Study of Performance f(Plant Species & Loading)
- Field Study of Performance f(Plant Species & Harvesting)
- Field Studies of GI Systems Cache & Salt Lake County

FIELD EVALUATION OF BMPS



- Evaluation of Three Typical Post-Construction, Vegetated BMPs
- Three Rainfall Events
- Flow and Pollutant Reduction Assessment

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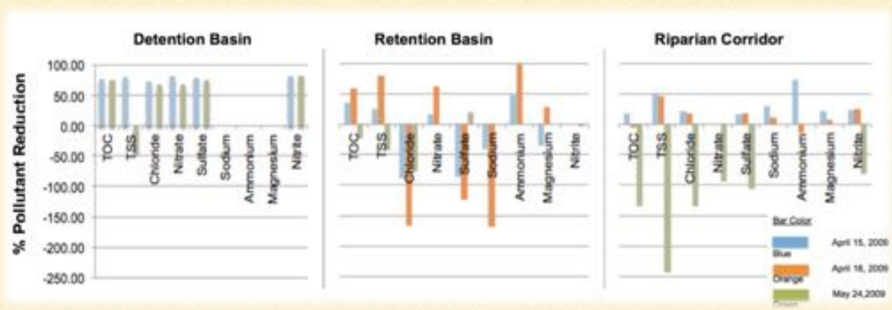
RESULTS



- Wet Detention Basin Only BMP Providing Consistent Pollutant Removal & Peak Flow Reduction
  - 78 to 83% Reduction of Flow
  - 66 to 83% Reduction of Pollutant Mass Loading
- From Hydrographs – Water Retention w/In BMPs Vital to Reducing Pollutant Loads in BMPs

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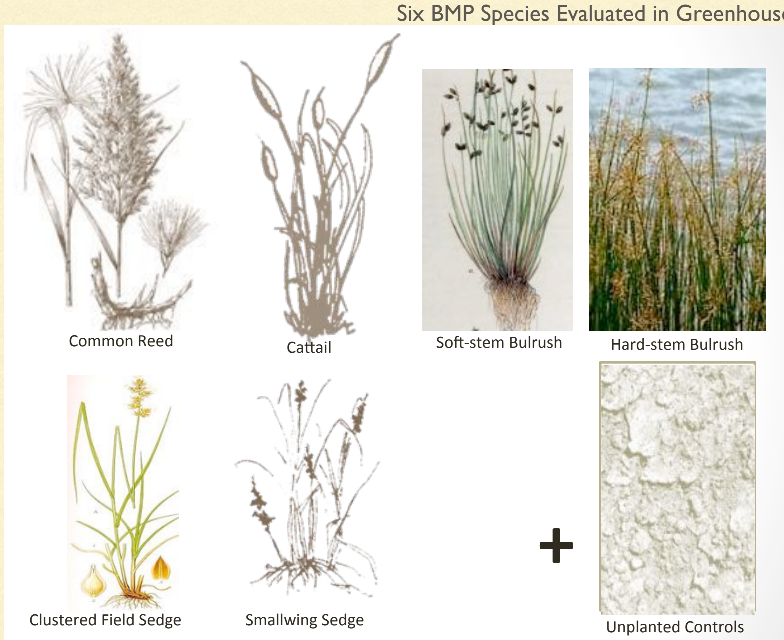
VEGETATIVE IMPACTS ON STORMWATER QUALITY IMPROVEMENTS

- Greenhouse Study
  - Six Plant Species
  - N & Metals Removal Performance
- Field Demonstration Study
  - Three Plant Species & Controls
  - N & Metal Uptake
  - Growth & Harvesting in Northern Utah Climate

Six BMP Species Evaluated in Greenhouse Study



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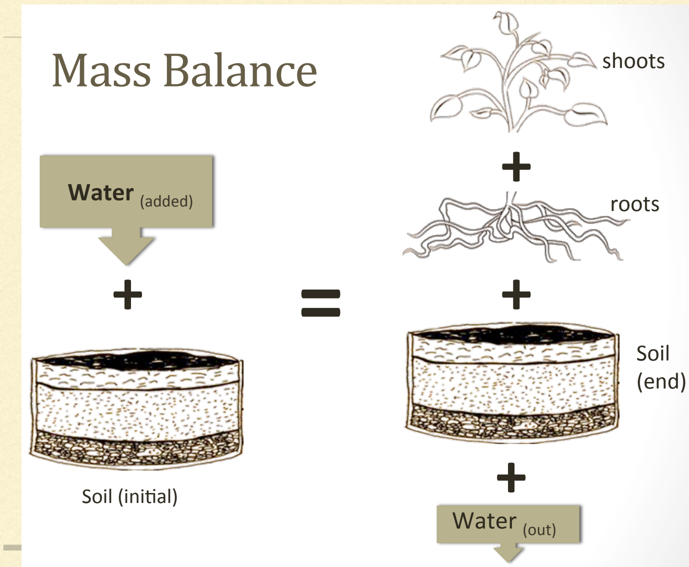
GREENHOUSE STUDY



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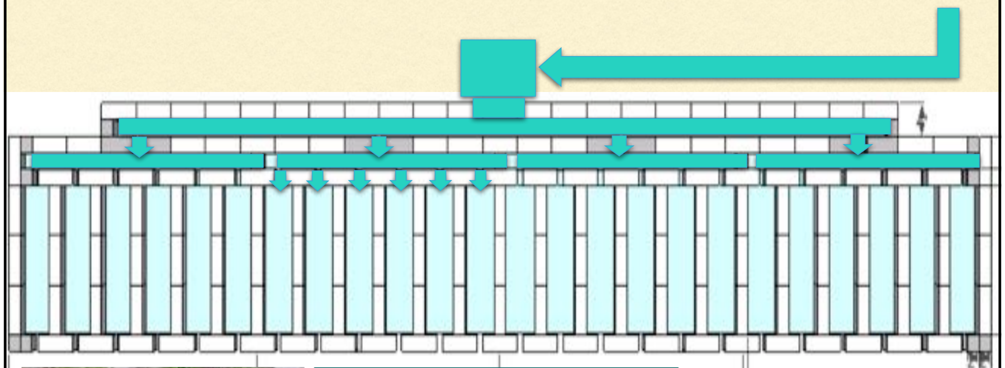
FINDINGS OF GREENHOUSE STUDY

- Any Planted System Maintains Long-Term Infiltration Rates
- >80% Retention of Cu, Pb, Zn by Soil
- Roots & Shoots Actively Take Up TN
- Significant Plant Variability in Pollutant Uptake
  - Sedge Had Consistently Higher Removal of All Pollutants than Other Species, Concentrated in Above Ground Tissue

FIELD DEMONSTRATION SITE



FIELD DEMONSTRATION SITE

Treatment Areas Planted with One of Three Species or Allowed to Naturally Seed

Small Wing Sedge
(*Carex spp.*)

Maximilian Sunflower
(*Helianthus maximillian*)

Cattail (*Typha latifolia*)

Naturally Seeded

FIELD DEMONSTRATION SITE FINDINGS

- Plant Growth Stabilizes Over 3 Yr Period
  - No Benefit to More than Annual Harvesting for Metals
  - N & P Recovery Increase w/2x Year Harvesting
- Plant Species Selection has Significant Impact on Pollutant Uptake
  - Sedges > Uptake Cu, Zn than Sunflower or Cattails
  - Sedges > Uptake Total-N, and Total-P than Sunflower
- Sedges Store Pollutants Preferentially in Above Ground Tissue for "Easy" Harvesting

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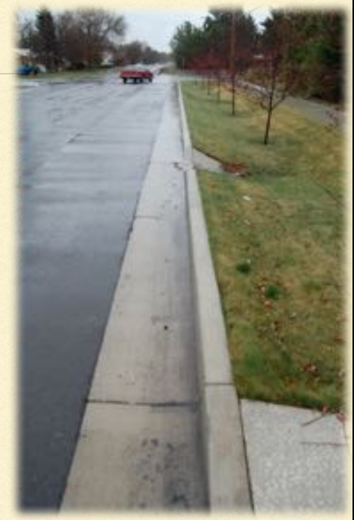
TWO GI STUDY AREAS

- **300 East Logan, UT**

- **Public Utilities Salt Lake City**

300 EAST LOGAN

- **Curb Cut Bioswale**
- **Planted with Turf Grass & Pear Trees**
- **Sample**
  - **Influent to Bays**
  - **Pore Water @ Two Depths – N&P**
  - **Soil Cores for Metals Analysis**



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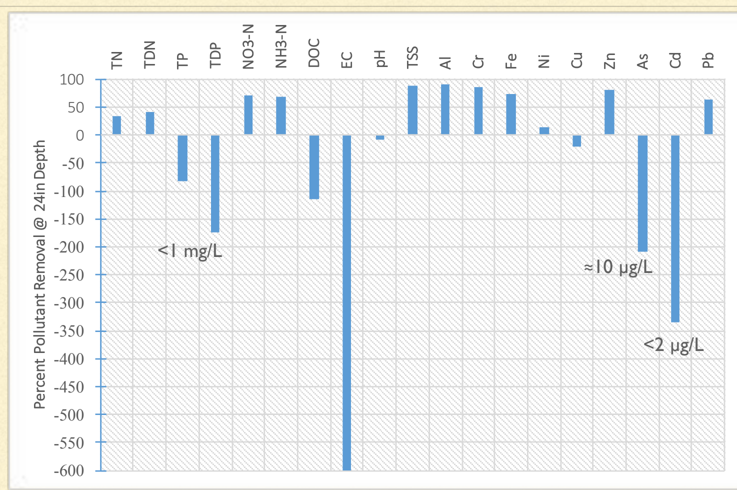
300 EAST POLLUTANT REMOVAL – GLOBAL AVERAGE SEVEN EVENTS



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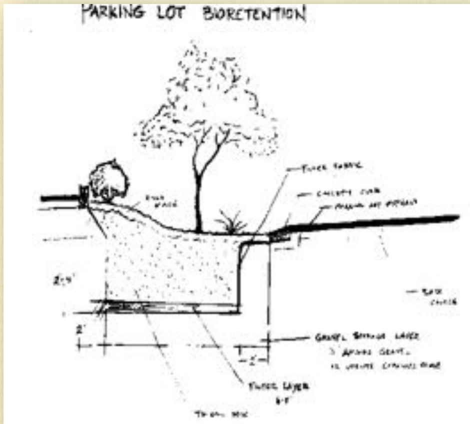
PUBLIC UTILITIES, SLC



- Parking Lot ”Bioretention” System
- Site Split Into Two Filter Layer Treatment Areas
- East End Contains Utelite Expanded Shale, West End Contains Pea Gravel Filter Layer

PUBLIC UTILITIES, SLC

- Water Collected During Storm Events Using Isco 6712 Autosampler
- Gutters at Edge of Parking Lot With Level Actuator that Signals Autosampler
- Sampler & Actuator Installed in Original Access Wells, However No Samples Could Be Collected Due to High Permeability of Both Media

PUBLIC UTILITIES, SLC

- Installation of New "Sump" Wells w/Sealed Collection Pipe Segment Below Screen
- Screened Section Located Beneath Each Filter Layer
- Monitor Water Passing through Filter Layer

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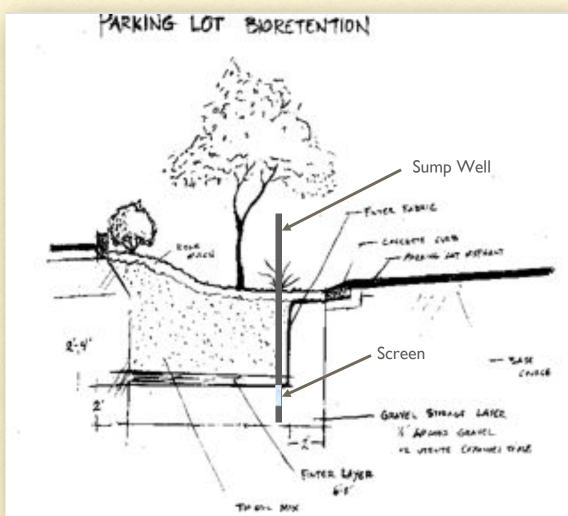
PUBLIC UTILITIES, SLC



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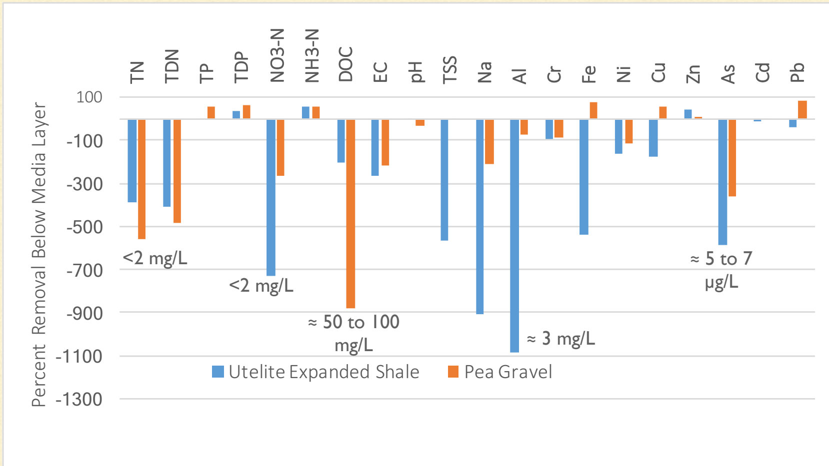
PUBLIC UTILITIES POLLUTANT REMOVAL – GLOBAL AVERAGE TEN EVENTS



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DO THESE SYSTEMS WORK?

ABSOLUTELY… SORT OF

RAINFALL EVENTS COMPLETELY CONTAINED

- Over Last 15 Mo @ Both Sites
  - Multiple 25 Year Storms
  - Multiple 10 Year Storms
- No Overflow/Discharge to Surface Water
- 100% Pollutant Load Reduction to Surface Water
- Groundwater Loading On-Going Concern

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CONCLUDING REMARKS

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WHAT HAVE WE LEARNED?

- Focus on Collection and Conveyance
  - Historically Critical
  - But Increasingly Impactful
  - Not Sustainable

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WHERE DO WE NEED TO GO?

- Focus on Distributed Treatment & Multifunctional Solutions
  - Integration of GI Into Local Landscapes
  - Design for Ecosystem Services
  - Design for Sustainable Systems

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WHAT DO WE STILL NEED TO KNOW?

- Impact of Diversion from Surface Water
  - Pollutant Reduction Benefits to Surface Water Ecosystems
    - Habitat &
    - WQ Improvements
  - Ground Water Affects
    - Increased Water Availability
    - WQ Impairment?

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QUESTIONS?

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